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The Determination of Carbamate and Urea Pesticides in Industrial and Municipal Wastewater: Method 632

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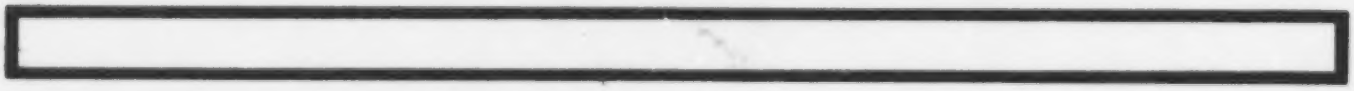

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THE DETERMINATION OF CARBAMATE AND UREA PESTICIDES IN INDUSTRIAL AND MUNICIPAL WASTEWATER

Method 632

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ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This is a high performance liquid chromatographic (HPLC) method appliicable to the determination of selected pesticides in municipal and industrial discharges as provided under 40CFR 136.1. A sample is solvent extracted with methylene chloride using a separatory funnel. The extract is exchanged to methanol or acetonitrile during concentration. HPLC conditions are described which permit measurement with an ultraviolet detector.

A total of 21 pesticides are included in the method scope.

17. KEY WORDS AND DOCUMENT ANALYSIS

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THE DETERMINATION OF CARBAMATE AND UREA PESTICIDES
IN INDUSTRIAL AND MUNICIPAL WASTEWATER

METHOD 632

1. Scope and Application

1.1 This method covers the determination of certain carbamate and urea pesticides. The following parameters can be determined by this method:

Parameter	STORET No.	CAS No.
Aminocarb	--	2032-59-9
Barban	--	101-27-9
Carbaryl	39750	63-25-2
Carbofuran	81405	1563-66-2
Chlorpropham	--	101-21-3
Diuron	39650	330-54-1
Fenuron	--	101-42-8
Fenuron-TCA	--	4482-55-7
Fluometuron	--	2164-17-2
Linuron	--	330-55-2
Methiocarb	--	2032-65-7
Methomyl	39051	16752-77-5
Mexacarbate	--	315-18-4
Monuron	--	150-68-5
Monuron-TCA	--	140-41-0
Neburon	--	555-37-3
Oxamyl	--	23135-22-0
Propham	39052	122-42-9
Propoxur	--	114-26-1
Siduron	--	1982-49-6
Swep	--	1918-18-9

1.2 This method cannot distinguish monuron from monuron-TCA and fenuron from fenuron-TCA. Results for the paired parameters are reported as monuron and fenuron respectively.

1.3 This is a high performance liquid chromatographic (HPLC) method applicable to the determination of the compounds listed above in industrial and municipal discharges as provided under 40 CFR 136.1. Any modification of this method beyond those expressly

permitted, shall be considered a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.4 The method detection limit (MDL, defined in Section 15) for many of the parameters are listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the use of liquid chromatography and in the interpretation of liquid chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

1.6 When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identifications should be supported by at least one additional qualitative technique.

2. Summary of Method

2.1 A measured volume of sample, approximately 1-liter, is solvent extracted with methylene chloride using a separatory funnel. The methylene chloride extract is dried and concentrated to a volume of 10 mL or less. HPLC chromatographic conditions are described which permit the separation and measurement of the compounds in the extract by HPLC with a UV detector.[1,2]

2.2 This method provides an optional Florisil column cleanup procedure to aid in the elimination or reduction of interferences which may be encountered.

3. Interferences

3.1 Method interferences may be caused by contaminants in solvents, reagents, glassware and other sample processing apparatus that lead to discrete artifacts or elevated baselines in liquid chromatograms. All reagents and apparatus must be routinely demonstrated to be free from interferences under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.5.

3.1.1 Glassware must be scrupulously cleaned.[3] Clean all glassware as soon as possible after use by thoroughly rinsing with the last solvent used in it. Follow by washing with hot water and detergent and thorough rinsing with tap and reagent water. Drain dry, and heat in an oven or muffle furnace at 400°C for 15 to 30 min. Do not heat volumetric ware. Thermally stable materials such as PCBs, might not be eliminated by this treatment. Thorough rinsing with acetone and pesticide quality hexane may be substituted for the heating. After drying and cooling, seal and store glassware

in a clean environment to prevent any accumulation of dust or other contaminants. Store inverted or capped with aluminum foil.

3.1.2 The use of high purity reagents and solvents helps to minimize interference problems. Purification of solvents by distillation in all-glass systems may be required.

3.2 Matrix interferences may be caused by contaminants that are coextracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature and diversity of the industrial complex or municipality sampled. The cleanup procedure in Section 11 can be used to overcome many of these interferences, but unique samples may require additional cleanup approaches to achieve the MDL listed in Table 1.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound must be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified [4-6] for the information of the analyst.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete or composite sampling.

5.1.1 Grab sample bottle - Amber borosilicate or flint glass, 1-liter or 1-quart volume, fitted with screw caps lined with TFE-fluorocarbon. Aluminum foil may be substituted for TFE if the sample is not corrosive. If amber bottles are not available, protect samples from light. The container and cap liner must be washed, rinsed with acetone or methylene chloride, and dried before use to minimize contamination.

5.1.2 Automatic sampler (optional) - Must incorporate glass sample containers for the collection of a minimum of 250 mL. Sample containers must be kept refrigerated at 4°C and protected from light during compositing. If the sampler uses a peristaltic pump, a minimum length of compressible silicone rubber tubing may be used. Before use, however, the compressible tubing must be thoroughly rinsed with methanol, followed by repeated rinsings with reagent water

to minimize the potential for contamination of the sample. An integrating flow meter is required to collect flow proportional composites.

5.2 Glassware (All specifications are suggested. Catalog numbers are included for illustration only.)

5.2.1 Separatory funnel - 2000-mL, with TFE-fluorocarbon stopcock, ground glass or TFE stopper.

5.2.2 Drying column - Chromatographic column 400 mm long x 19 mm ID with coarse fritted disc.

5.2.3 Chromatographic column - 400 mm long x 19 mm ID with coarse fritted disc at bottom and TFE-fluorocarbon stopcock (Kontes K-420540-0224 or equivalent).

5.2.4 Flask, round bottom - 500-mL, with standard taper to fit rotary evaporator.

5.2.5 Vials - Amber glass, 10 to 15 mL capacity with TFE-fluorocarbon lined screw cap.

5.3 Rotary evaporator.

5.4 Water bath - Heated, with concentric ring cover, capable of temperature control (± 2°C). The bath should be used in a hood.

5.5 Balance - Analytical, capable of accurately weighing to the nearest 0.0001 g.

5.6 Filtration apparatus - As needed to filter chromatographic solvents prior to HPLC.

5.7 Liquid chromatograph - High performance analytical system complete with high pressure syringes or sample injection loop, analytical columns, detector and strip chart recorder. A guard column is recommended for all applications.

5.7.1 Gradient pumping system, constant flow.

5.7.2 Column - 30 cm long x 4 mm ID stainless steel packed with μ Bondapak C_{18} (10 μm) or equivalent. This column was used to develop the method performance statements in Section 14. Alternative columns may be used in accordance with the provisions described in Section 12.1.

5.7.3 Detector - Ultraviolet, capable of monitoring at 254 nm and 280 nm. This detector has proven effective in the analysis of wastewaters and was used to develop the method performance statements in Section 14. Alternative

detectors may be used in accordance with the provisions described in Section 12.1.

6. Reagents

6.1 Reagent water - Reagent water is defined as a water in which an interferent is not observed at the method detection limit of each parameter of interest.

6.2 Acetone, acetonitrile, hexane, methylene chloride, methanol - Pesticide quality or equivalent.

6.3 Ethyl ether - Nanograde, redistilled in glass if necessary. Must be free of peroxides as indicated by EM Quant test strips. (Available from Scientific Products Co., Cat. No. P1126-8, and other suppliers.) Procedures recommended for removal of peroxides are provided with the test strips. After cleanup, 20 mL ethyl alcohol preservative must be added to each liter of ether.

6.4 Sodium sulfate - (ACS) Granular, anhydrous. Heat treat in a shallow tray at 400°C for a minimum of 4 h to remove phthalates and other interfering organic substances. Alternatively, heat 16 h at 450-500°C in a shallow tray or Soxhlet extract with methylene chloride for 48 h.

6.5 Florisil - PR grade (60/100 mesh). Purchase activated at 1250°F and store in dark in glass container with ground glass stopper or foil-lined screw cap. Before use activate each batch at least 16 h at 130°C in a foil covered glass container.

6.6 Acetic acid - Glacial.

6.7 Stock standard solutions (1.00 µg/µL) - Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions.

6.7.1 Prepare stock standard solutions by accurately weighing approximately 0.0100 g of pure material. Dissolve the material in pesticide quality acetonitrile or methanol and dilute to volume in a 10-mL volumetric flask. Larger volumes may be used at the convenience of the analyst. If compound purity is certified at 96% or greater, the weight may be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards may be used at any concentration if they are certified by the manufacturer or by an independent source.

6.7.2 Transfer the stock standard solutions into TFE-fluorocarbon-sealed screw cap vials. Store at 4°C and protect from light. Frequently check stock standard solutions for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

6.7.3 Stock standard solutions must be replaced after six months or sooner if comparison with check standards indicates a problem.

7. Calibration

7.1 Establish HPLC operating parameters equivalent to those indicated in Table 1. The HPLC system may be calibrated using either the external standard technique (Section 7.2) or the internal standard technique (Section 7.3).

7.2 External standard calibration procedure:

7.2.1 For each parameter of interest, prepare calibration standards at a minimum of three concentration levels by adding accurately measured volumes of one or more stock standards to a volumetric flask and diluting to volume with acetonitrile or methanol. One of the external standards should be representative of a concentration near, but above, the method detection limit. The other concentrations should correspond to the range of concentrations expected in the sample concentrates or should define the working range of the detector.

7.2.2 Using injections of 10 µL of each calibration standard, tabulate peak height or area responses against the mass injected. The results can be used to prepare a calibration curve for each parameter. Alternatively, the ratio of the response to the mass injected, defined as the calibration factor (CF), may be calculated for each parameter at each standard concentration. If the relative standard deviation of the calibration factor is less than 10% over the working range, the average calibration factor can be used in place of a calibration curve.

7.2.3 The working calibration curve or calibration factor must be verified on each working shift by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

7.3 Internal standard calibration procedure. To use this approach, the analyst must select one or more internal standards similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Due to these limitations, no internal standard applicable to all samples can be suggested.

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest by adding volumes of one or more stock standards to a volumetric flask. To each calibration standard, add a known constant amount of one or more internal standards, and dilute to volume with acetonitrile or methanol. One of the standards should be representative of a concentration near, but above, the method detection limit. The other concentrations should correspond to the range of concentrations expected in the sample concentrates, or should define the working range of the detector.

7.3.2 Using injections of 10 µL of each calibration standard, tabulate the peak height or area responses against the concentration for each compound and internal standard. Calculate response factors (RF) for each compound as follows:

$$RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
C_{is} = Concentration of the internal standard in µg/L.
C_s = Concentration of the parameter to be measured in µg/L.

If the RF value over the working range is constant, less than 10% relative standard deviation, the RF can be assumed to be invariant and the average RF may be used for calculations. Alternatively, the results may be used to plot a calibration curve of response ratios, A_s/A_{is} against RF.

7.3.3 The working calibration curve or RF must be verified on each working shift by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

7.4 The cleanup procedure in Section 11 utilizes Florisil chromatography. Florisil from different batches or sources may vary in adsorptive capacity. To standardize the amount of Florisil which is used, the use of lauric acid value is suggested. This procedure[7] determines the adsorption from hexane solution of lauric acid, in mg, per g of Florisil. The amount of Florisil to be used for each column is calculated by dividing this factor into 110 and multiplying by 20 g.

7.5 Before using any cleanup procedure, the analyst must process a series of calibration standards through the procedure to validate elution patterns and the absence of interference from the reagents.

8. Quality Control

8.1 Each laboratory using this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated.

8.1.1 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of the rapid advances occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications to the method are made, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in acetonitrile or methanol 1000 times more concentrated than the selected concentrations.

8.2.2 Using a pipet, add 1.00 mL of the check sample concentrate to each of a minimum of four 1000-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Table 2 provides single operator recovery and precision for most of the carbamate and urea pesticides. Similar results should be expected from reagent water for all compounds listed in the method. Compare these results to the values

calculated in Section 8.2.3. If the data are not comparable, review potential problem areas and repeat the test.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.3.1 Calculate upper and lower control limits for method performance as follows:

$$\text{Upper Control Limit (UCL)} = R + 3s$$
$$\text{Lower Control Limit (LCL)} = R - 3s$$

where R and s are calculated as in Section 8.2.3. The UCL and LCL can be used to construct control charts[8] that are useful in observing trends in performance.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as $R \pm s$. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternatively, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly.[8]

8.4 The laboratory is required to collect in duplicate a portion of their samples to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one spiked sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular parameter does not fall within the control limits for method performance, the results reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 13.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Before processing any samples, the analyst must demonstrate through the analysis of a 1-liter aliquot of reagent water that all glassware and reagents interferences are under control. Each time a set of samples is extracted or there is a change in reagents, a laboratory reagent blank must be processed as a safeguard against laboratory contamination.

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be

analyzed to monitor the precision of the sampling technique. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as chromatography with a dissimilar column, or ratio of absorbance at two or more wavelengths may be used. Whenever possible, the laboratory should perform analysis of quality control materials and participate in relevant performance evaluation studies.

9. Sample Collection, Preservation, and Handling

9.1 Grab samples must be collected in glass containers. Conventional sampling practices[9] should be followed; however, the bottle must not be prerinsed with sample before collection. Composite samples should be collected in refrigerated glass containers in accordance with the requirements of the program. Automatic sampling equipment must be as free as possible of plastic and other potential sources of contamination.

9.2 The samples must be iced or refrigerated at 4°C from the time of collection until extraction.

9.3 All samples must be extracted within seven days and completely analyzed within 40 days of extraction.

10. Sample Extraction

10.1 Mark the water meniscus on the side of the sample bottle for later determination of sample volume. Pour the entire sample into a 2-liter separatory funnel.

10.2 Add 60 mL methylene chloride to the sample bottle, seal, and shake 30 s to rinse the inner walls. Transfer the solvent to the separatory funnel and extract the sample by shaking the funnel for 2 min with periodic venting to release excess pressure. Allow the organic layer to separate from the water phase for a minimum of 10 min. If the emulsion interface between layers is more than one third the volume of the solvent layer, the analyst must employ mechanical techniques to complete the phase separation. The optimum technique depends upon the sample, but may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods. Collect the methylene chloride extract in a 250-mL Erlenmeyer flask.

10.3 Add a second 60-mL volume of methylene chloride to the sample bottle and repeat the extraction procedure a second time, combining the extracts in the Erlenmeyer flask. Perform a third extraction in the same manner.

10.4 It is necessary to exchange the extract solvent to hexane if the Florisil clean up procedure is to be used. For direct HPLC analysis the extract solvent must be exchanged to a solvent (either

methanol or acetonitrile) that is compatible with the mobile phase. The analyst should only exchange a portion of the extract to HPLC solvent if there is a possibility that cleanup may be necessary.

10.5 Pass a measured fraction or all of the combined extract through a drying column containing about 10 cm of anhydrous sodium sulfate and collect the extract in a 500-mL round bottom flask. Rinse the Erlenmeyer flask and column with 20 to 30 mL of methylene chloride to complete the quantitative transfer.

10.6 Attach the 500-mL round bottom flask containing the extract to the rotary evaporator and partially immerse in the 50°C water bath.

10.7 Concentrate the extract to approximately 5 mL in the rotary evaporator at a temperature of 50°C. Other concentration techniques may be used if the requirements of Section 8.2 are met.

10.8 Add 50-mL of hexane, methanol, or acetonitrile to the round bottom flask and concentrate the solvent extract as before. When the apparent volume of liquid reaches approximately 5 mL remove the 500-mL round bottom flask from the rotary evaporator and transfer the concentrated extract to a 10-mL volumetric flask, quantitatively washing with 2 mL of solvent. Adjust the volume to 10 mL.

10.9 Stopper the volumetric flask and store refrigerated at 4°C if further processing will not be performed immediately. If the extracts will be stored longer than two days, they should be transferred to TFE-fluorocarbon-sealed screw-cap bottles.

10.10 Determine the original sample volume by refilling the sample bottle to the mark and transferring the water to a 1000-mL graduated cylinder. Record the sample volume to the nearest 5 mL.

11. Cleanup and Separation

11.1 Cleanup procedures may not be necessary for a relatively clean sample matrix. The cleanup procedure recommended in this method has been used for the analysis of various industrial and municipal effluents. If particular circumstances demand the use of an alternative cleanup procedure, the analyst must determine the elution profile and demonstrate that the recovery of each compound of interest for the cleanup procedure is no less than 85%.

11.2 The following Florisil column cleanup procedure has been demonstrated to be applicable to the five pesticides listed in Table 3. It should also be applicable to the cleanup of extracts for the other carbamate and urea pesticides listed in the scope of this method.

11.2.1 Add a weight of Florisil (nominally 20 g) predetermined by calibration (Section 7.4 and 7.5), to a chromatographic column. Settle the Florisil by tapping the column. Add anhydrous sodium sulfate to the top of the Florisil to form a layer 1 to 2 cm deep. Add 60 mL of hexane to wet and rinse the sodium sulfate and Florisil. Just prior to exposure of the sodium sulfate to air, stop the elution of the hexane by closing the stopcock on the chromatography column. Discard the eluate.

11.2.2 Adjust the sample extract volume to 10 mL with hexane and transfer it from the volumetric flask to the Florisil column. Rinse the flask twice with 1 to 2 mL hexane, adding each rinse to the column.

11.2.3 Drain the column until the sodium sulfate layer is nearly exposed. Elute the column with 200 mL of 20% ethyl ether in hexane (V/V) (Fraction 1) using a drip rate of about 5 mL/min. Place a 500-mL round bottom flask under the chromatography column. Elute the column again, using 200 mL of 6% acetone in hexane (V/V) (Fraction 2), into a second flask. Perform a third elution using 200 mL of 15% acetone in hexane (V/V) (Fraction 3), and a final elution with 200 mL of 50% acetone in hexane (V/V) (Fraction 4), into separate flasks. The elution patterns for five of the pesticides are shown in Table 3.

11.2.4 Concentrate the eluates to 10 mL with a rotary evaporator as described in Section 10.7, exchanging the solvent to acetonitrile or methanol as required.

12. Liquid Chromatography

12.1 Table 1 summarizes the recommended operating conditions for the liquid chromatograph. Included in this table are estimated retention times and method detection limits that can be achieved by this method. An example of the separations achieved by this column is shown in Figure 1. Other HPLC columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

12.2 Calibrate the system daily as described in Section 7. The standards and extracts must be in the solvent (acetonitrile or methanol) compatible with the mobile phase.

12.3 If the internal standard approach is being used, add the internal standard to sample extracts immediately before injection into the instrument. Mix thoroughly.

12.4 Inject 10 µL of the sample extract. Record the volume injected to the nearest 0.05 µL, and the resulting peak size in area or peak height units.

12.5 The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time can be used to calculate a suggested window size for a compound. However, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

12.6 If the response for the peak exceeds the working range of the system, dilute the extract and reanalyze.

12.7 If the measurement of the peak response is prevented by the presence of interferences, further cleanup is required.

13. Calculations

13.1 Determine the concentration of individual compounds in the sample.

13.1.1 If the external standard calibration procedure is used, calculate the amount of material injected from the peak response using the calibration curve or calibration factor in Section 7.2.2. The concentration in the sample can be calculated as follows:

$$\text{Concentration, } \mu g/L = \frac{(A)(V_t)}{(V_i)(V_s)}$$

where:

A = Amount of material injected, in nanograms.
V_i = Volume of extract injected in µL.
V_t = Volume of total extract in µL.
V_s = Volume of water extracted in mL.

13.1.2 If the internal standard calibration procedure was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.3.2 as follows:

$$\text{Concentration, } \mu g/L = \frac{(A_s)(I_s)}{(A_{is})(RF)(V_o)}$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
I_s = Amount of internal standard added to each extract in µg.
V_o = Volume of water extracted, in liters.

13.2 Calculate and report fenuron-TCA as fenuron and monuron-TCA as monuron. Report results in micrograms per liter without correction for recovery data. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

13.3 For samples processed as part of a set where the laboratory spiked sample recovery falls outside of the control limits in Section 8.3, data for the affected parameters must be labeled as suspect.

14. Method Performance

14.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.[10] The MDL concentrations listed in Table 1 were obtained using reagent water or river water.[2,11]

14.2 In a single laboratory, the average recoveries presented in Table 2 were obtained using this method.[2,11] The standard deviations of the percent recoveries of these measurements are also included in Table 2.

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TABLE 1

CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

Parameter	Mobile Phase*	Retention Time (Min)	UV Wavelength (nm)	Method Detection Limit (µg/L)
Mexacarbate	A	8.7	254	0.52
Propoxur	A	14.3	280	0.11
Monuron	A	14.4	254	0.003
Carbaryl	A	17.0	280	0.02
Propham	A	17.2	254	0.07
Diuron	A	19.5	254	0.009
Linuron	A	21.0	254	0.009
Methiocarb	A	21.4	254	0.02
Chlorpropham	A	21.8	254	0.03
Barban	A	22.3	254	0.05
Neburon	A	24.3	254	0.012
Propoxur	B	2.0	280	0.11
Methomyl	B	6.5	254	8.9
Carbaryl	B	14.1	280	0.02
Diuron	B	15.5	254	0.009
Linuron	B	17.9	254	0.009
Propoxur	C	1.7	280	0.11
Carbofuran	C	3.5	280	3.2
Fluorometuron	C	3.6	254	11.1
Oxamyl	D	3.2	254	9.2

*Mobile Phase:
A Methanol/1% acetic acid, programmed linearly from 5 to 95% methanol at 2.0 mL/min flow rate and at ambient temperature.
B Acetonitrile/water, programmed linearly from 10% to 100% acetonitrile in 30 min at a flow rate of 2.0 mL/min.
C 50% acetonitrile in water at a flow rate of 2.0 mL/min.
D 35% methanol in water at a flow rate of 2.0 mL/min.

Column: µ Bondapak C_{18} (10 µm) packed in a 30 cm long x 4 mm ID stainless steel column, with a Whatmann Co. PELL ODS (30-38 µm) guard column, 7 cm long x 4 mm ID.

TABLE 2

SINGLE OPERATOR ACCURACY AND PRECISION

Parameter	Sample Type*	Spike (µg/L)	No. of Analyses	Average Percent Recovery	Standard Deviation %
Fluorometuron	1	50	7	93.9	7.0
	2	50	7	80.0	7.2
	4	1724	7	99	11.6
Propoxur	1	550	7	94.5	1.7
	3	2200	3	105	3.0
	4	550	7	87.2	7.3
	5	0.5	5	93	6.0
Oxamyl	1	100	7	87	8.4
	2	53	7	84.9	5.5
	2	1080	7	89.8	2.7
Methomyl	1	100	4	74.4	2.4
	3	30660	4	48.2	2.8
	2	100	7	91.8	2.8
	2	1960	7	94.4	1.9
Diuron	1	10	4	89.8	1.0
	3	500	4	56.1	5.0
	2	10	7	90.0	2.5
	2	400	7	95.7	3.2
	5	0.05	5	98	4.7
Linuron	1	10	4	95.0	3.4
	3	4000	4	72.2	5.1
	2	10	7	93.0	1.5
	2	210	7	103	4.6
	5	0.05	5	99	4.7
Carbofuran	1	37	7	87.8	2.7
	4	148	7	99.3	1.4
Barban	5	0.3	5	98	4.1
Carbaryl	5	0.1	5	101	4.1
Chlorpropham	5	0.2	5	95	3.9
Methiocarb	5	0.2	5	95	2.6
Mexacarbate	5	4.0	5	96	3.5
Monuron	5	0.05	5	97	1.7
Neburon	5	0.05	5	96	6.6
Propham	5	0.3	5	88	5.9

* = Sample Type
1 = Reagent Water
2 = Municipal wastewater
3 = Industrial process water, pesticide manufacturing
4 = Industrial wastewater, pesticide manufacturing
5 = River Water

TABLE 3

FLORISIL FRACTIONATION PATTERNS

Parameter	Percent Recovery by Fraction			
	No. 1	No. 2	No. 3	No. 4
Diuron	0	0	24	58
Linuron	0	13	82	0
Methomyl	0	0	0	84
Oxamyl	0	0	92	0
Propachlor	0	94	0	0

Florisil eluate composition by fraction
Fraction 1 - 200 mL of 20% ethyl ether in hexane
Fraction 2 - 200 mL of 6% acetone in hexane
Fraction 3 - 200 mL of 15% acetone in hexane
Fraction 4 - 200 mL of 50% acetone in hexane

Figure 1. Liquid chromatogram of diuron, linuron and methomyl on Column 1. For conditions, see Table 1.